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Case Report

Multiple Intelligence's and Computational Thinking

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Abstract

Stakeholders from education are determined to introduce computational thinking (CT) and programming much earlier into the educational process. Thus, according to international trends, programming has grown progressively, reaching a significant focus within the EU and other countries. Since future research needs to be undertaken to investigate the interrelationship between CT skills and competencies, we designed a project to be carried out during one year with 9-year-old students attending a primary school of Basic Education. This article presents the results achieved until we had the chance since the COVID pandemic disturbed the investigation's final part.

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Introduction

In recent years, there has been an increased effort to introduce coding and computational thinking in early childhood education (Bers, 2018; Özbey & Köyceğiz, 2020; Papadakis, 2020; Wakil, Khdir, Sabir, & Nawzad, 2019). Learning to code involves children in new ways of thinking that some researchers have called computational thinking (Barr & Stephenson, 2011; International Society for Technological Education and the Computer Science Teachers Association, 2011; Wing, 2006).

The act of programming and thinking in terms of computational thinking (CT) is increasing, getting more importance in society. Papert (2000) identified the potentialities of introducing children's programming languages as an incubator of powerful ideas, that is, as a tool for engaging children in new ways of thinking and thinking about thinking (Papert, 2005). Involve children in code activities helps develop algorithmic thinking, a unique mode of thought distinct from those encountered in the arts, mathematics, and other sciences. It is a competence that has become important for everyone in the modern world (Rogozhkina & Kushnirenko, 2011). Around the world, countries have started to change their curriculums. In 2012 the UK began introducing Computer Science (CS) to all students. As part of its Smart

Nation initiative, Singapore has labelled developing CT as a national capability. Other countries like Finland, South Korea, China, Australia and New Zealand have launched large-scale efforts to introduce CT in schools as either a part of new CS curricula or integrated into other subjects. In the USA, former President Barack Obama called on all K-12 students to be equipped with CT skills as part of an initiative in 2016 called Computer Science for All. So, according to this, governments and stakeholders from education are determined to introduce CT and programming much earlier into the educational process. Thus, and according to international trends, programming has grown progressively, reaching a significant focus worldwide.

When we look back, the idea of introducing computer programming into a classroom environment is not new, and it had already begun in 1960. Seymour Papert was the first to identify the potential of introducing programming languages as a potent incubator of ideas. Programming was a tool to engage children in new ways of thinking, but much more importantly, it can put the student in a role in which he can think about the thought process.

Since future research needs to be undertaken to investigate the interrelationship between CT skills and competencies (Angeli & Giannakos, 2020) we designed a one year project with 9-year-old students attending a primary school of Basic Education. This communication describes the work done until we had the chance since the pandemic didn't allow us to proceed until the very end. We have completed 2/3 of the process with very important results that show the power of the CT. In this article, we present some results obtained with the methodology used in class with the LEGO Mindstorm EV3 robot and the influence on students' Multiple Intelligences (from Howard Gardner), namely: *Linguistics; Logical-Mathematician; Musical; Body-Kinesthesis; Spatial-Visual; Interpersonal; Intrapersonal*.

Computational Thinking

The focus on programming is relevant, but the direction of ideas, creativity, collaboration, and problem-solving is even more critical, taking a motivating pedagogical perspective. In addition to developing students' creativity in computer science, programming promotes a broader view of different computer uses and contributes to the development of CT. Also, this activity focuses on skills children develop from practicing programming and algorithms … enables the development of qualities such as abstract thinking, problem-solving, pattern recognition, and logical reasoning (Angeli & Giannakos, 2020).

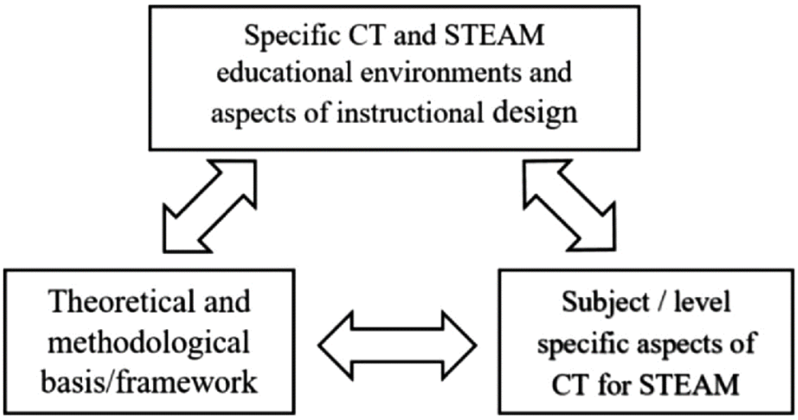

Figure 1. Conceptual framework of CT education. from: (Pears, et al, 2019)

Wing (2006) defines the concept of CT as the ability to use computational methods and concepts to solve problems. That´s why we have STEM (Science Technology, Engineering and Mathematics) in Figure 1.

Since the concept of CT has been introduced, shape studies have emerged and evaluated it in the context of different programming learning activities (Grover, Pea, & Cooper, 2015). Among these studies and project we can see the growing importance of CT, starting since pre-school context (Gerosa, 2021) and (Bakala, 2021) that states *promoting CT at an early age enhances children's analytical capacities and introduces them to new mental tools that are useful for collaborative problem solving and expression*.

Other studies explain the concept of computer thinking and gives some particularities:

- Wing (2017) define CT is the thinking process used to formulate a problem and find a solution that can be implemented by a computer.
- For Furber (2012) CT is a process of identifying aspects and characteristics of the world that surrounds us and applying tools and techniques of Computer Science, which will allow us to understand the systems and processes under analysis.
- For Yadav (2014), computer science is a mental process that enables and promotes abstraction in problem analysis to create automated solutions.

Contrasting what we might think, CT is not exclusively connected to computers, though we automatically make the association. Computer literacy and CT are considered essential skills that students must develop (P21's Framework for 21st Century Learning, 2015), as was formerly the reading and writing capacities, or the performing of arithmetic operations. So nowadays, we have the 4 "C's": Creativity & Innovation, Critical Thinking, Communication and Collaboration, Figure 2.

Figure 2. Four "C's" from: http://etec.ctlt.ubc.ca/510wiki/21st_Century_Learning_Skills 25/09/2020

The study from Brennan, Chunge and Hawson (2011) identifies the context of programming to practices that may be important to develop essential abilities for the 21st century where we live.

- Iterative and incremental action - A programming project is developed in stages. Only when part of the project works appropriately creates the following steps, which can often be tested in isolation.

- Testing and Debugging - After completing a program (or a step), you must test and make sure everything works as intended. Often, errors are encountered at this stage and in project sharing that had gone unnoticed throughout the program building process and should be corrected.

- Decomposition and Abstraction - Complex problems can be divided into simpler problems. For example, if we want to draw several same polygons, it is possible to create a program to draw one. Drawing the rest will be simple by reworking or repeating the previous program. But suppose we have to draw several regular polygons. In that case, we can draw a regular square, pentagon, and hexagon and then generalize by getting a program that lets you draw any regular polygon, indicating the number of sides.

The same authors go further deep and present key concepts related to CT that are very evident when students work on a computer program:

- *Sequences* - Whenever we execute a series of commands in programming, they are interpreted sequentially. The order in which they appear is important. Often just changing the order of two elements will give us completely different results.

- *Cycles* - The same sequence can be executed multiple times. After making programs with command sequences, students will recognize repeating patterns. Using cycles, more demanding in CT than a simple sequence, will make programs smaller, more readable and easier to understand.

- *Events*- Events that trigger a particular action. Conditions Programming is not always linear. Under certain conditions and using decision-making structures, the program may take different directions.
- *Operators*- Students will use operators to perform mathematical and/or logical operations.
- *Data Variables*- In programming, it will be necessary to store, retrieve and update values stored in variables.
- *Parallel Execution* -When we execute a program, many actions often start in parallel. You will need to understand this concept and plan carefully so that events happen when you need.

So, according to the previous statements is easy to understand that CT influences a large variety of fields such as biology, chemistry, linguistics, psychology, economics and mathematics. It helps to solve problems, design systems, and understand the power and limits of human and machine intelligence. It is a skill that enables all students to beware and learn to have some competence on it. In addition, students who can think computationally can better conceptualize and understand computer-based technology and are better equipped to work in modern society.

We are talking about competencies fitting in jobs that didn't exist right now, but these same competencies will be needed in a few years to come, so the education system should start to prepare the students for their (our) future in advance. Education improves students' lives and life skills since it prepares the people for a world that does not yet exist, involving technologies that have not yet been invented and present technical and ethical challenges that we are not aware of… yet.

Multiple Intelligences

The traditional type of teaching has not been successful for all the students we have had during the last years. The different types of generations that attend in School had changed… and changed a lot. Going from the Baby Boomers (born between 1946 and 1964), Gen X (born between 1965 and 1980, the Gen Y or Millennials (born between 1980 and 1994), separated into two classes, the Gen Y.1 (25-29 years old) and the Gen Y.2 (29-39 years old), and the last one the Gen Z.

Inside of this last generation is our target group of study, the newest generation to be named born between 1996 and 2015. They are currently between 5-24 years old, and they are a generation of students with a high dropout rate in School. So, it is essential to understand how this new generation thinks, work, develop their skills, interact with each other in a wide variety of cross situations (Figure 3).

Figure 3. The latest generations names from: https://www.dailymail.co.uk/femail/article-8109077/Which-generation-fall-into.html; 16/10/2021

Howard Gardner (1995) helps us understand how the multiple intelligences work (Figure 4) and why it's so important to recognize the variety of human intelligence's. Some of this intelligence may become the central point of the activity in a classroom environment. They are contributing to the better development of students towards adulthood. Therefore, education, and particularly the School, should provide the basis for the best understanding of our world – and concerning the various worlds: the physical world, the biological world, the world of human beings, and the world of ourselves.

Figure 4. The initial 7 Howard Gardner multiple intelligences from: https://learningabledkids.com/learning-styles/gardners-multiple-intelligences 15/10/2021

The same author understands that the traditional way of testing a person's intelligence fails in many cases, tending to be unfair to specific individuals while producing no accurate results. So, after investigating, he comes to seven different kinds of intelligence: Linguistic, Logical/Mathematical, Musical, Bodily-Kinesthetic, Spatial, Interpersonal and Intrapersonal. These seven types reflect the way that we interact with others. Some years later, and since the world is progressing, two more classes were added: the Naturalistic and the Existential. In our study, and due to the ages of the students (very young), we will use the first set of seven (Figure 4).

Objectives

The main objective of this project was to promote Computer Science, particularly the use of CT as an interesting, appealing and intellectually inspiring subject. Students should be creative while delivering basic concepts of CT that do not depend on specific software or systems. Through our approach was possible to implement the activities without resorting to educational solutions that rely on very advanced technologies or knowledge.

We can mention the specific objectives:

- describing a problem;
- identifying the essential details needed to solve a problem;
- divide the problem into small logical steps;
- use the different steps to create a process (algorithm) that solves the problem;
- evaluate the process.

These skills are transversal to other scientific areas, like Mathematics, for example. To solve mathematical problems, students need to apply the previous set of goals, the so-called George Polya heuristics (Polya, 1945).

Methodology

Designed a mixed methodology, quantitative (standard anonymous questionnaire, a pre-test, following-test and post-test) and qualitative (observational with video and photos, during the several sessions). This design was chosen because of the students' age, nine years old so that the quantitative aspects could be complemented with the observation in each session.

The School principal was informed of the goals, procedure, and use of the data for research, so we have the authorization to perform the study. Since the class teacher is part of the team, there was no need to have his consent. In addition, all the parents/responsible were asked for proper permission on an informed consent sheet. Before the pre questionnaire was administered, the students were given instructions on how to complete them and were guaranteed the confidentiality of data processing. Then, one member of the research team went to the School to administer during the first session the standardized anonymous questionnaire (paper and pencil) to all the students in a single 30 to 40-minute session. Following this first session, and after gathering the initial results of the pre questionnaire, comes the hands-on sessions.

The practical sessions' work was divided into the three periods of study (First: October, November and December; Second: January, February and March; Third: April, May and June). Two times per month, the classroom was divided into small groups (6 groups: four with four students and two with five students), then a member of the team performed different activities with each small group in a separate room, meaning that none of the groups was looking what the others were doing, or how they perform in the different activities. The main idea is that robots will act as a tool within the classroom. The Robot is not the theme of the study itself.

The set of activities was applied to the 4th-grade class composed of 26 students (13 females) of a School of the 1st cycle in the city of Bragança (Portugal). The students, separated into groups, program the Robot to go through different mazes within the classroom. They collect on the selected path the various issues related to the curriculum areas. They are programming the Robot using CT for this and, in parallel, are studying and remembering the most important concepts of the curriculum. Every 15 days in the morning, the students have a set of activities, meaning at least 1.5 hours of interaction and work in a group methodology. The group work component was chosen since the class, and the class teacher usually uses it in a usual way to work since the 1st year of schooling. Each random group of students (between 4 and 5) was assigned in the first session. Each of them needs to program the Robot to fulfil the route chosen by themselves to collect questions arranged on the floor related to the various curriculum areas. The questions are in close envelopes with three types of difficulty (1, 2 and 3). The difficulty is connected to the route that the Robot needs to perform to pick them.

This type of activity, CT activities, are not fully conditioned to the use of technologies. The implementation of these activities without technology is very much based on a constructivist approach: students are challenged based on some simple rules, and, in solving them, they are designing, implementing, testing new ideas on their own. By the time they are in the computer or, in this case, using a robot to program the path, this will allow them to realize that the ideas are at their fingertips and that they can be fulfilled.

One of the main options taken by researchers to measure the effects of this methodology is the Howard Gardner Multiple Intelligence scale, previously mentioned in this document. This was applied before starting the activity (pre questionnaire), in the middle and end of the training. Unfortunately, and due to the pandemic situation (COVID-19), the last part of the research could not be concluded since the schools were closed after 12 March 2020. Yet, the results gathered until the end of the second period were enough to draw some interesting conclusions about this activity.

The activities have some interesting characteristics:

- They do not rely directly on computers, tablets or other devices. This avoids complicated processes, such as learning platforms and tools, requiring sufficient current equipment for students and teachers to have programming skills or tools.
- The activities allow children to discover answers for themselves rather than just receiving solutions or algorithms to follow. A constructivist approach is encouraged, promoting students to realize that they can find solutions to problems independently, rather than receiving a resolution to apply to the problem.
- Activities are fun and attractive, not just busywork. Generally, the explanations are pretty brief - the teacher presents the materials and some rules, and the students follow the challenge from there.

CT enables children to solve problems, design systems, and understand the power and limits of human and machine intelligence. The children who succeed using this powerful tool are evidence of their ability to conceptualize, understand, and use computer-based technology and are better prepared for today's world and the future.

Results and Discussion

As we already stated in the methodology section, due to the pandemic situation (COVID-19) and consequently the interruption of all teaching activities in the 1st cycle, we could not present extensive data compared to what we would like. However, the pre-questionnaire on Multiple Intelligences was applied before the start of the activities, results in Table 1 and Figure 5.

On average, students have higher results in the Body-Kinesthetic and Musical components than the Logical-Mathematical and Intrapersonal. This has allowed us to readjust some of the tasks to appeal more to the parts that we think can be improved, especially the Logical-Mathematical, thus finding a better balance in the seven components. The group of activities for the initial two months was conducted considering the pre-test results. The questions of the main themes of the curriculum were connected to Mathematics, Mother Language and Sciences Nature.

Besides the video and photos for every activity (some presented here), the observation from the teacher and one member of the researchers' team allows us to find that students engaged in the activities offered since the first day with great interest.

A single day activity consists of 2 separated parts.

1. Working without any technology (all students) 50 minutes. Some examples:
    a. The Magic Square activity;
    b. The Mysterious Algorithm;
    c. I'm the Robot.
2. Working with the Robot (small groups) 20 minutes:
    a. Learn to use the action boxes on the LEGO Mindstorm EV3 interface in a small area.
    b. Driving the Robot on the floor without any guidance;
    c. Moving the Robot on the floor from point A until point B inline;
    d. Going the Robot from point A until point B with obstacles in the way;
    e. Driving the Robot in an unknown maze collecting questions with different punctuation (1, 2 and 3) and different themes (Mathematics, Mother Language and Sciences Nature).

After the first part, where students were confronted with interesting questions that made them think, the effort of each small group (from 4 to 5 students) on driving the Robot to collect a possible number of questions in time was fully demonstrated. At the same time, they faced the different mazes, and the clock started ticking.

The research team decided to give an initial 5 minutes to test and analyse each group's situation. Then they had 15 minutes to collect the answers that were spread around the floor in the room with the help of the Robot. An essential aspect is that after the Robot starts the route, there is no turning back to the initial position, making the task more complex. They always need to think according to the exact place and moment they are.

Table 1. Pre-test results on the 7 Howard Gardner multiple intelligences

Students	Linguistic	Logical - Mathematical	Musical	Bodily-Kinesthetic	Spatial-Visual	Interpersonal	Intrapersonal
MC	13	8	12	13	14	12	20
JN	10	14	15	15	10	14	11
RVF	14	16	20	20	15	18	9
BA	13	12	17	17	14	15	15
DB	12	16	15	19	10	13	14
AR	19	18	18	20	19	20	16
TA	20	20	20	20	20	17	14
EV	16	16	20	18	18	20	15
SC	16	13	15	19	14	17	11
PT	18	16	18	15	15	17	16
DV	16	16	20	20	16	16	11
RD	19	18	20	20	17	15	20
LA	16	15	20	16	16	15	14
IS	17	15	19	17	17	17	16
DR	17	18	15	19	18	19	16
TC	16	13	13	17	13	13	13
AF	13	16	20	18	17	17	14
MB	17	11	14	20	18	20	12
RQ	19	15	20	19	19	18	12
RN	15	11	17	17	15	17	13
RP	20	15	17	20	17	18	17
MA	10	12	17	15	11	17	13
RT	18	8	18	15	17	16	8
CN	17	15	14	18	10	18	10
AG	15	19	20	15	19	18	12
JR	16	15	16	17	14	16	10
Mean	15,8	14,7	17,3	17,7	15,5	16,7	13,5

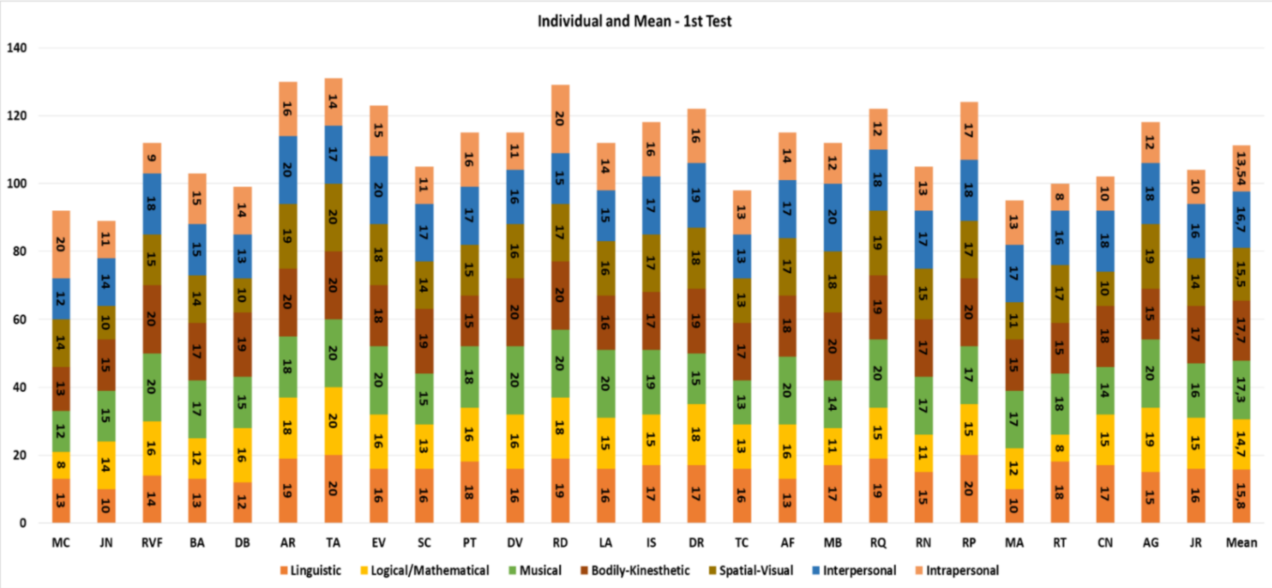

Figure 5. Results of first application

We have done a total of 8 sessions of work with the groups (the big group and the small groups):

1. Knowledge of CT without any type of technologies exemplified here in Figure 6 and Figure 7;

Figure 6. Working in small groups

Figure 7. Working in small groups

2. Initial work with the software associated with the LEGO Mindstorm EV3 robot, for application of some of the routines Figure 8.

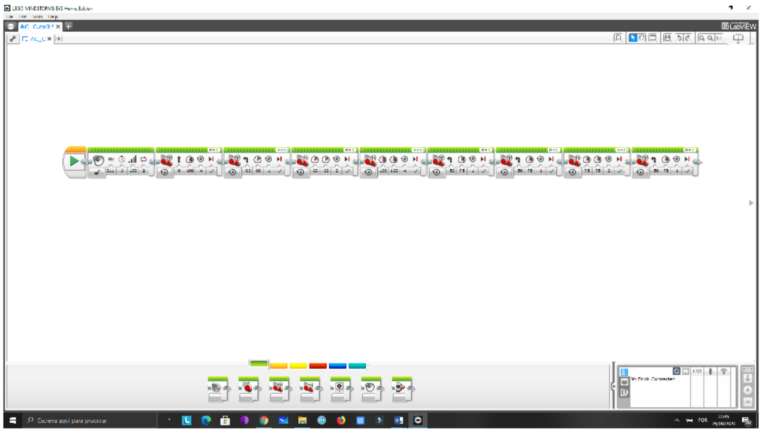

Figure 8. Programing with MindStorm EV3 interface from A to B

After applying the model of tasks that we designed and until the start of the pandemic situation in March 2020, we collected more data from the students (Table 2, Figure 9) to compare to the initial one.

Table 2. Pos-test results on the 7 Howard Gardner multiple intelligences

Students	Linguistic	Logical - Mathematical	Musical	Bodily-Kinesthetic	Spatial-Visual	Interpersonal	Intrapersonal
MC	14	17	12	16	17	13	18
JN	15	17	15	17	16	13	10
RVF	15	18	20	20	16	14	9
BA	16	17	17	17	14	16	15
DB	15	16	15	19	16	15	14
AR	19	19	18	20	19	20	15
TA	20	20	20	20	20	17	13
EV	17	19	20	18	18	20	15
SC	16	18	15	19	14	17	12
PT	17	17	18	16	15	17	15
DV	16	16	20	20	16	18	11
RD	19	18	20	20	17	16	16
LA	16	16	20	16	16	15	14
IS	17	16	19	17	17	17	16
DR	17	18	15	19	18	19	16
TC	16	15	13	17	16	15	13
AF	14	16	20	18	17	17	14
MB	17	17	14	20	18	20	11
RQ	19	15	20	19	19	18	12
RN	15	15	17	17	15	17	12
RP	20	15	17	19	17	18	15
MA	13	15	17	16	15	17	13
RT	18	16	18	16	17	16	10
CN	17	17	16	18	14	18	10
AG	15	19	20	15	19	18	14
JR	16	17	17	17	14	16	14
Mean	16,5	16,9	17,4	17,9	16,5	16,8	13,3

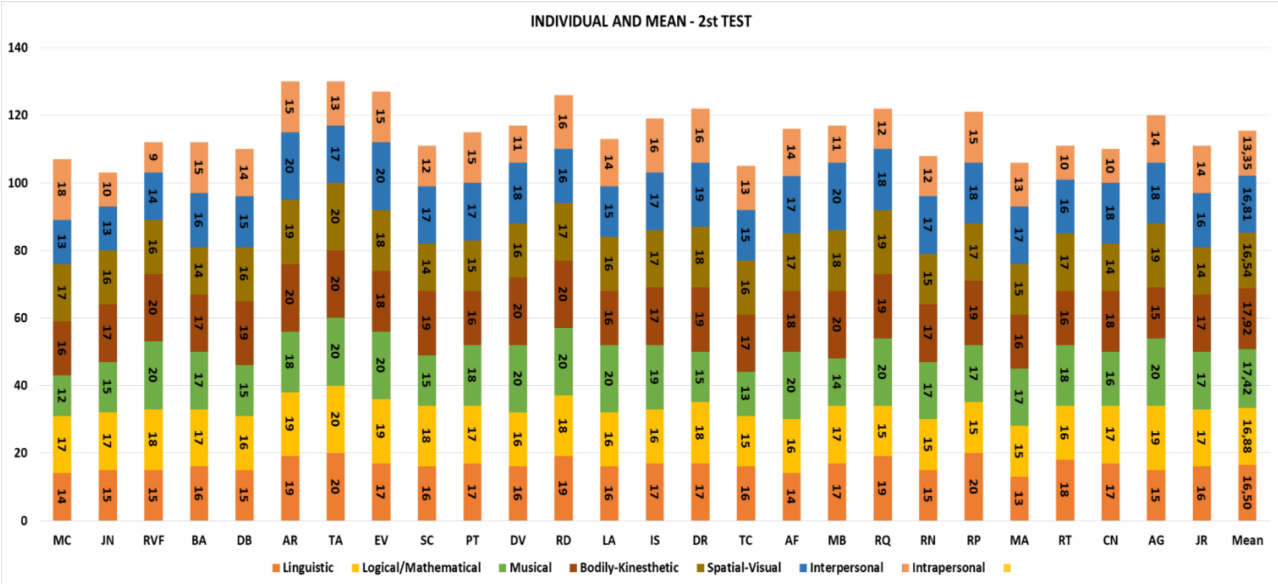

Figure 9. Results of the second test

There is an evident increase of two components that initially have lower results, the Mathematical and the Space-Visual (Figure 10). This quantitative data, combined with the qualitative, observational recording and photo sessions, shows us a tendency to influence the design activities positively.

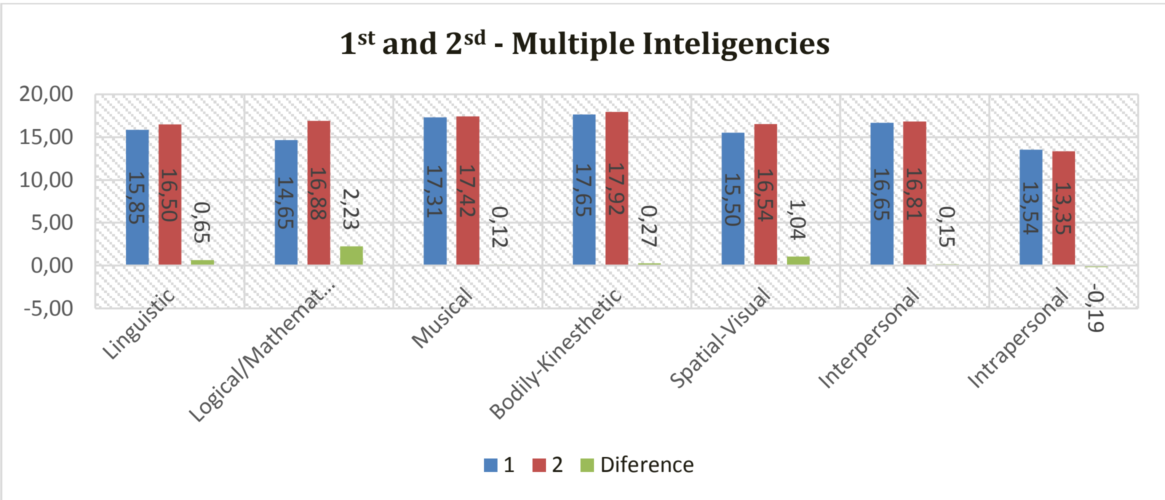

Figure 10. Differences between first and second

The components that display this meaningful raise were the Logical/Mathematical from 14,65 to 16,88 (+2,33) and the Spatial-Visual from 15,50 to 16,54 (+1,04). It’s clear that the Robot's activities, by driving the Robot in the different mazes, force students to analyse their behaviour, allowing them to have a more global view on some problem-solving skills and the spatial dimensions.

Recent studies (Fajrina, 2020; Sisman, Kucuk & Yaman, 2020) discuss the role of spatial reasoning and its importance in STEM (Science, Technology, Engineering, Mathematics). Also, STEM aims to develop thinking, reasoning, teamwork, and investigation (Fajrina, 2020). Along with these ideas, the 21st-century skills are aligned with the four "C's" Critical thinking, Creativity, Communication, and Collaboration, which are considered the key elements to develop in the following years.

The activities performed by the students developed areas that connected the four "C's" stated before. Using the 7 Multiple Intelligence questionnaires, we can check the increase in almost every area, except the Intrapersonal. We believe that is normal since the actions tend to face students in interpersonal development by talking with each other, discussing the instructions to implement, and the following steps.

Conclusions

Helping children use Computational thinking is now seen as a didactic strategy that enables them to create learning autonomy. The learning process is always a work in process. Also, Computational thinking is based on a paradigm that focuses on developing critical thinking and self-reflective thinking. Computational thinking can be applied to different areas of study such as biology, chemistry, linguistics, psychology, economics and mathematics. Computational thinking is a tool that allows students to understand computer-based technology and is, therefore, better equipped to work in modern society and allows the development of skills such as autonomy and self-responsibility, which are essential skills for lifelong learning.

During this project and their several workshops, we saw that it is possible to implement activities that allow children to use computational thinking to obtain different solutions and learn different paths. We observe in situ how children learn to use reasoning and plan to solve problems.

In the workshops, it was evident how they used different strategies of computational thinking:

- Decompose tasks by breaking them down into smaller, more manageable parts;
- Thinking logically and algorithmically, determining the sequence of actions needed to achieve a goal, and recognizing patterns or repetitions;

- They resort to abstraction, paying attention to crucial features while ignoring unnecessary details;
- Testing and error detection to go beyond steps.

Another vital aspect is tools like Gardner's Multiple Intelligences, and nowadays, we know that intelligence is more than a simple word. We as educators need to pay attention to the different characteristics of our students and establish new paths so the Education process can prepare convenient the leaders of tomorrow.

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Author Contribution Statement

Pedro TADEU: *Conceptualization, literature review, data collection, data analysis and document editing.*

Carlos BRIGAS: *Document editing.*

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